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Effect of Feeding DAS-59122-7 Corn Grain and Nontransgenic Corn Grain to Individually Fed Finishing Steers[1]

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ABSTRACT

An experiment was conducted to evaluate feeding transgenic corn containing the cry34Ab1 and cry35Ab1 genes from a Bacillus thuringiensis strain and the phosphinothricin acetyltransferase (pat) gene from Streptomyces viridochromogenes to finishing cattle compared with nontransgenic corn. Expression of the cry34Ab1 and cry35Ab1 genes confers resistance to corn rootworms, and the pat gene confers tolerance to herbicides containing glufosinate-ammonium. Sixty crossbred steers (396 kg) were individually fed either transgenic corn (DAS-59122-7; 59122), a near-isogenic, nontransgenic control (Control), and a conventional, nontransgenic corn for 109 d to evaluate nutritional equivalency (20 steers/treatment). The corn was coarsely rolled (geometric mean diameter = 4,200 μm) and treatments were offered in the finishing diet at 82% of diet DM. Gain ($P = 0.38$) and G:F ($P = 0.80$) were similar between 59122 and Control with a tendency for a difference in DMI ($P = 0.08$). When adjusted using the statistical analysis of false discovery rate, DMI, ADG, and G:F were not different between Control and 59122 ($P > 0.33$). No differences were observed between Control and 59122 for HCW, marbling score, LM area, fat depth, or calculated USDA YG ($P > 0.12$). The genetically modified corn DAS-59122-7 was nutritionally equivalent to a near-isogenic control when fed to finishing steers. Feeding corn grain containing these transgenic traits did not influence steer performance or carcass quality.

Key words: cattle, corn, finishing, genetic enhancement, maize, transgenic plant

INTRODUCTION

Western corn rootworms (**CRW**) are responsible for more annual crop damage in the United States than all other insects (Metcalf, 1986). Although pesticide treatment and crop rotation strategies have historically been used to control the impact of CRW on crop yield, the potential economic and biological benefits of CRW-resistant corn grain are substantial (Oehme and Pickrell, 2003).

Corn provides a large portion of the dietary energy and comprises the largest component in beef feedlot diets (Vasconcelos and Galyean, 2007). Thus, genetically enhanced corn grain and silage are fed widely for livestock consumption. Although there has been research on use of glyphosate-tolerant (Erickson et al., 2003) and *Bacillus thuringiensis* (**Bt**) corn (Folmer et al., 2002;Vander Pol et al., 2005) fed to finishing cattle, there is currently no data available on evaluating a combination of both genetic enhancements in the same corn grain for feedlot cattle.

A new transgenic corn grain is available that is resistant to CRW and is herbicide tolerant. This new transgenic corn line (event DAS-59122-7) contains the *cry*34Ab1 and *cry*35Ab1 genes from a Bt strain and the phosphinothricin acetyltransferase (***pat***) gene from *Streptomyces viridochromogenes*. Expression of the *cry*34Ab1 and *cry*35Ab1 genes confers resistance to CRW, and the *pat* gene confers tolerance to herbicides that

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contain the active ingredient glufosinate-ammonium (i.e., Liberty; Bayer AG, Leverkusen, Germany).

The objective of this study was to compare corn grain from DAS-59122-7 with grain from a nontransgenic, near-isogenic corn for individually fed feedlot cattle performance and carcass characteristics. The hypothesis was that feeding this new transgenic corn would not impact performance of individually fed cattle.

MATERIALS AND METHODS

Cattle and Treatments

Sixty Continental × British crossbred steers (BW = 396.2 ± 14.8 kg) were individually fed using Calan gates (American Calan, Northwood, NH) during a 109-d experiment at the University of Nebraska-Lincoln Agricultural Research and Development Center near Mead, NE. Steers used in this experiment were managed according to guidelines recommended by FASS (1999). All procedures used in this experiment were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee. Steers were purchased as weaned calves in the fall of 2005 and the experiment was conducted from January 27, 2006, to May 15, 2006. Dietary treatments consisted of a nontransgenic, near-isogenic control (**Control**), a reference, nontransgenic Pioneer brand hybrid 35P12 (**Reference**), and corn grain from DAS-59122-7 (**59122**). The dietary ingredients consisted of 82% of the treatment corn that was dry-rolled, 8.5% alfalfa hay, 5% molasses, and 4.5% supplement (Table 1). Supplement was fed as a dry meal supplement and was identical for each of the 3 grain treatments. Rumensin and Tylan (Elanco Animal Health, Greenfield, IN) were fed for target consumption of 300 and 90 mg/steer daily, respectively. Diets were formulated to meet or exceed steer requirements (NRC, 1996) for protein, Ca, P, and K as well as trace minerals. Supplements were formulated so that the corn source with the lowest CP would have sufficient supplemental protein to meet requirements. Because the same supplement was used in each of the 3 treatment diets, protein was sufficient across treatments.

Cattle were fed once daily at 0700 h by hand-delivery. Diets were mixed daily using a truck equipped with a Roto-Mix model 420 (Roto-Mix, Dodge City, KS) mixer-delivery box with scales. Feed refusals were recorded and collected as needed (approximately twice weekly). Feed samples were collected weekly and dried in a forced air oven at 60°C for 48 h for accurate determination of DMI and G:F. Feed samples were composited by month and analyzed for nutrient composition (Table 1) at a commercial laboratory (Ward Laboratories Inc., Kearney, NE). Prior to trial initiation, steers were trained to the Calan gate system and adapted to the facilities for a 28-d period. Following adaptation, steers were also grown by limit-feeding a diet consisting of 65% dry-rolled, nontransgenic corn, 20% alfalfa haylage, 10.5% grass hay, and

Table 1. Diet composition and nutrient composition of diets fed to finishing steers (% of dietary DM basis)

	Treatment[1]		
Item	Control	59122	Reference
Ingredient			
Dry-rolled corn[2]	82.0	82.0	82.0
Alfalfa hay	8.5	8.5	8.5
Molasses	5.0	5.0	5.0
Supplement	4.5	4.5	4.5
Fine ground sorghum	1.811	1.811	1.811
Limestone	1.233	1.233	1.233
Urea	0.843	0.843	0.843
Salt	0.300	0.300	0.300
Tallow	0.117	0.117	0.117
Potassium chloride	0.105	0.105	0.105
Trace mineral premix[3]	0.050	0.050	0.050
Monensin 80 premix[4]	0.016	0.016	0.016
Vitamin premix[5]	0.015	0.015	0.015
Tylosin 40 premix[6]	0.010	0.010	0.010
Nutrient composition[7]			
CP	12.71	12.58	12.33
Ca	0.703	0.706	0.706
P	0.302	0.335	0.294
K	0.755	0.766	0.749

[1]Treatments included nontransgenic near-isogenic control (Control), DAS-59122-7 (59122), or a nontransgenic commercially available reference (Pioneer hybrid 35P12; Reference). The transgenic corn (59122) contained the *cry*34Ab1 and *cry*35Ab1 genes from a *Bacillus thuringiensis* strain and the phosphinothricin acetyltransferase (*pat*) gene from *Streptomyces viridochromogenes*.

[2]Corn was dry-rolled to 4,200 µm mean diameter.

[3]Premix included (g/kg of premix): 130 Ca, 10 Co, 15 Cu, 2 I, 100 Fe, 80 Mn, and 120 Zn.

[4]Formulated to contain monensin at 30 mg/kg of diet DM (176 g/kg of premix).

[5]Contained (per kg of premix): 29,900 kIU of vitamin A, 6,000 kIU of vitamin D, and 7 kIU of vitamin E.

[6]Formulated to contain tylosin at 11 mg/kg of diet DM (88 g/kg of premix).

[7]Composition as a percent of diet DM based on ingredient analysis of feed samples collected weekly throughout the experiment.

4.5% supplement. Steers were fed 8.2 kg for 45 d during this limit-feeding period. Individual steer weights from 3 consecutive days (d −1, 0, and 1) were averaged to calculate initial BW. Steers were maintained on the limit-fed diet and intake during the weighing period to minimize variation in gastrointestinal fill. The BW collected on d −1 and d 0 were stratified, and steers were blocked into light (15 steers), middle (27 steers), and heavy (18 steers) weight blocks. Within each weight block, steers were assigned randomly to dietary treatment (20 steers/treatment). On trial initiation (d 1) cattle were implanted with Synovex-Choice (Fort Dodge Animal Health, Overland Park, KS).

Steers were adapted to finishing diets with 3 adaptation diets by increasing treatment corn and decreasing alfalfa. Adaptation diets included 30, 20, and 14% alfalfa hay with 60.5, 70.5, and 76.5% treatment corn fed for 3, 5, and 5 d, respectively, followed by finishing diets fed for the remainder of the experiment. After feeding for 109 d, steers were slaughtered at a commercial abattoir (Greater Omaha Pack, Omaha, NE) where slaughter order, hot carcass weight (**HCW**), and liver scores (Elanco Animal Health Field Guide) were recorded on the day of slaughter. Following a 48-h chill, KPH, fat depth at the 12th rib, and LM area data were collected. Marbling score was called by the USDA grader. Calculated USDA YG was derived from HCW, fat depth, KPH, and LM area (Boggs and Merkel, 1993). Carcass-adjusted performance was calculated based on HCW assuming a dressing percentage of 63% to calculate final BW, ADG, and G:F.

Corn Sources

Corn grains were supplied by Pioneer Hi-Bred (Johnston, IA) and produced under identity-preserved methods from growing, storage, processing, delivery, and feeding. The DAS-59122-7 corn grain was sourced from fields that received 2 sequential applications of glufosinate-ammonium herbicide (Liberty; Bayer) in a field trial in 2005 in Richland, Iowa. A nontransgenic control corn with comparable genetic background (Control) and one nontransgenic commercial reference corn (Pioneer hybrid 35P12; Reference) were produced separately at the same location. Treatment grains were delivered as needed in approximately 1,000-kg capacity large grain containers. Each corn was rolled to 4,200 µm geometric mean diameter particle size before delivery to avoid differences between corn sources due to particle size. All grains were also evaluated for expression of the Cry34Ab1 and Cry35Ab1 proteins using protein-specific ELISA methods (Pioneer). Mycotoxin analyses (MidWest Seed Services Inc., Brookings, SD) were conducted on all corn grains before diet preparation.

Statistical Analysis and Procedures

Data were analyzed using mixed procedure for ANOVA using SAS (SAS Inst. Inc., Cary, NC) for performance and carcass characteristics. Animal was the experimental unit and individual data were analyzed as a randomized complete block design, with block analyzed as a fixed effect. The comparison between the 59122 transgenic group and the Control group was the true comparison of interest in this study; therefore, estimate statements were used to generate the P-values for comparisons of individual performance and carcass measures. Differences due to treatment were considered significant when the F-test statistic had a probability level of less than 5% ($P < 0.05$).

When evaluating nutritional equivalency between a new transgenic product and its near-isogenic control, it is important to determine when the transgenic line causes a change in the mean response; but it is just as important to not falsely declare there is a change. The chance of falsely declaring 2 treatments' means different for at least one trait when a large set (20 or more) of traits is measured in an experiment is more than 90% (Milliken and Johnson, 1992). False Discovery Rate (**FDR**) is an adjustment method that minimizes the number of false discoveries (i.e., wrongly declaring a difference significant) while providing sufficient power to detect changes in means when, in fact, they have occurred. Using FDR maintains more power than procedures that control the experimentwise error rate; it provides a balance between finding too many differences between the isogenic and transgenic lines as significant and finding too few differences. The P-values generated from the estimate comparison statement were subjected to FDR, as described by Benjamini and Hochberg (1995). In the event of significant differences, or evaluating trends toward differences ($P < 0.10$), the Adjusted P-value (calculated from FDR) was used to determine if the difference was really due to treatment.

Data generated from the Reference grain treatment were used in the estimation of experimental variability; least squares mean values were generated for Reference, but comparisons between 59122 and Reference were to be generated only in the case of statistically significant differences between 59122 and Control treatment groups after application of FDR.

RESULTS AND DISCUSSION

Diets

Diets varied from 12.3 to 12.7% CP, and averaged 0.70% Ca, 0.31% P, and 0.76% K (Table 1), suggesting that the only differences observed should be due to corn traits and not protein or minerals. Composition of the different corn grains were similar and compared well with NRC (1996) feed composition tabular values for corn grain (Table 2). Levels of starch varied from 71.1 to 73.5%, oil varied from 4.2 to 4.6%, CP varied from 10.0 to 10.5%, and Ca, P, K, and Mg values (DM basis) were similar. Mycotoxin analysis demonstrated the absence of aflatoxin B_1 from all grains, a very low concentration (0.1 ppm) of vomitoxin in only 59122 grain, and

Table 2. Composition analysis of corn hybrids fed to finishing steers (all values expressed as % on a DM basis)

	Treatment[1]		
Item	Control	59122	Reference
DM	94.3	94.5	94.7
NDF	11.8	10.3	10.6
Starch	71.1	73.5	73.5
Oil	4.23	4.57	4.17
Ash	1.40	1.47	1.31
CP	10.47	10.30	10.00
Ca	0.01	0.01	0.01
P	0.29	0.33	0.28
K	0.33	0.35	0.33
Mg	0.10	0.11	0.10

[1]Treatments included nontransgenic, near-isogenic control (Control), DAS-59122-7 (59122), or a nontransgenic commercially available reference (Pioneer hybrid 35P12; Reference). The transgenic corn (59122) contained the *cry*34Ab1 and *cry*35Ab1 genes from a *Bacillus thuringiensis* strain and the phosphinothricin acetyltransferase (*pat*) gene from *Streptomyces viridochromogenes*.

low concentrations of fumonisin B_1 (approximately 2 to 5 ppm) in all 3 corn grains. Fumonisin B_1 content did not exceed the US FDA guidelines for dietary fumonisins in ruminant diets (USFDA, 2001). The ELISA analysis confirmed the presence of the Cry34Ab1 and Cry35Ab1 proteins in corn grain 59122 and their absence from Control and Reference corn grains. These data suggest that grain quality control was sufficient and that identity preservation was maintained throughout the experiment.

Performance

One steer was removed from the trial due to shoulder problems during initial weighing and was removed from the study. The reason for removal was unrelated to dietary treatment. Steers in this experiment weighed 396 kg at trial initiation (Table 3). Initial BW was not different between Control and 59122, as designed. Dry matter intakes were numerically greater for cattle fed 59122 compared with Control ($P = 0.08$). Corn source fed did not impact ADG ($P = 0.37$). As a result, G:F was not influenced by whether cattle were fed 59122 or Control corn. Steers fed 59122 had 6% greater DMI, 5% greater ADG, and 2% greater final BW than steers fed Control, but these differences were not statistically significant. When the P-values were adjusted using FDR statistics due to large number of variables evaluated, there were no differences detected in DMI, ADG, or G:F ($P > 0.33$) for cattle fed 59122 compared with Control.

Similar to performance, carcass characteristics were not different between Control and 59122. Carcasses had similar fat depth ($P = 0.29$) and marbling score ($P = 0.65$) between Control and 59122, suggesting cattle were finished to similar endpoints on these 2 treatments. No differences were observed in HCW ($P = 0.36$), LM area ($P = 0.12$), or KPH ($P = 0.21$). The cutability ($P = 0.20$) and calculated USDA YG ($P = 0.19$) were not different between cattle fed 59122 or Control grains. The only variable that tended to be different was dressing percentage ($P = 0.07$) between the Control and 59122 treatments. However, this trait is relatively meaningless due to inaccuracies in measuring final live BW before slaughter. Considering HCW were nearly identical between treatments, there were likely little real differences in weight gain between corn sources. When P-values for carcass traits are adjusted using FDR, no differences were detected between Control and 59122 for all carcass traits ($P > 0.20$).

As hypothesized, no differences were detected for performance or carcass characteristics for cattle fed the transgenic corn grain compared with its genetically similar, nontransgenic control. Because of the lack of differences between Control and 59122 treatments after FDR adjustment, it was not necessary to generate comparisons between the Reference and 59122 treatments. The inability to detect differences between the transgenic grain and the nontransgenic grain in this experiment agrees with previous research evaluating transgenic corn.

When evaluating CRW protection alone, similar observations have been reported for grazing or growing cattle (Folmer et al., 2002), feedlot cattle (Erickson et al., 2003; Vander Pol et al., 2005), dairy cattle (Folmer et al., 2002; Ipharraguerre et al., 2002; Grant et al., 2003), swine (Gaines et al., 2001b; Fischer et al., 2002), and poultry (Gaines et al., 2001a; Piva et al., 2001; Taylor et al., 2003).

Comparing previous research on growing-finishing beef cattle, Vander Pol et al. (2005) evaluated corn rootworm protected corn (Bt corn, event MON 863) when fed to finishing cattle. The authors concluded that feeding this CRW-protected grain had no effect on performance in one experiment and a slight improvement in ADG compared with cattle fed the nearly identical, nontransgenic corn in the other experiment. When compared with 2 commercially available hybrids in each study, one experiment had no differences whereas the other suggested that the Bt-corn slightly improved G:F. No differences were detected in carcass characteristics between any corn sources for both finishing experiments. The authors concluded that no negative effects on performance were detected when the Bt corn was fed to finishing cattle and that the subtle differences (improvements) observed for feeding Bt corn were likely due to energy content,

Table 3. Performance and carcass characteristics of steers fed a nontransgenic, near-isogenic control (Control), DAS-59122-7 (59122), or a nontransgenic commercially available reference (Reference)

Item	Control	59122	Reference[1]	SEM	*P*-value	Adjusted *P*-value[2]
Performance						
Initial BW, kg	395	396	394	2	0.795	0.844
Final BW,[3] kg	553	562	567	7	0.357	0.503
DMI, kg/d	9.51	10.11	9.89	0.25	0.083	0.333
ADG,[3] kg	1.45	1.53	1.58	0.06	0.377	0.503
G:F[3]	0.153	0.151	0.160	0.006	0.799	0.844
Carcass characteristics						
HCW,[4] kg	349	354	357	4	0.357	0.503
Dress, %	64.13	62.69	62.97	0.55	0.065	0.333
Marbling score[5]	463	475	508	19	0.651	0.801
LM area, cm^2	77.5	80.8	80.1	1.6	0.122	0.344
Fat depth, cm	1.04	0.95	0.97	0.06	0.294	0.503
% KPH	1.94	1.87	1.94	0.04	0.209	0.419
Calculated YG[6]	2.98	2.76	2.85	0.12	0.193	0.201
Cutability,[7] %	49.83	50.34	50.13	0.29	0.201	0.201

[1]Reference least squares means included for reference purposes only. True comparison of interest is 59122 vs. Control treatment.

[2]*P*-value adjusted using False Discovery Rate.

[3]Final BW and ADG calculated from hot carcass weight/0.63.

[4]HCW = hot carcass weight.

[5]400 = Slight^{o}, 450 = Slight^{50}, 500 = Small^{o}.

[6]Calculated YG = 2.5 + 0.98425 × fat (cm) + 0.2 × KPH (%) + 0.00837× HCW (kg) − 0.0496 × LM area (cm^2).

[7]Cutability = 51.34 − 2.27717 × fat (cm) − 0.462 × KPH (%) − 0.02048 × HCW (kg) + 0.1147 × LM area (cm^2).

not incorporation of the transgenic trait. Folmer et al., (2002) evaluated a different Bt corn silage with growing calves and concluded that Bt corn silage had no consistent effect on performance due to incorporation of the Bt trait (Cry1Ab protein). No differences were detected in growing calves by grazing corn stalks containing either event MON 863 (Vander Pol et al., 2005) or Cry1Ab (Folmer et al., 2002) when compared with corn stalks from nontransgenic, genetically similar corn.

Lack of differences due to herbicide tolerance in this experiment agrees with previous research evaluating glyphosate-tolerant corn and soybeans fed to dairy cattle (Hammond et al., 1996; Donkin et al., 2003), pigs (Cromwell et al., 2001; Gaines et al., 2001b; Stanisiewski et al., 2001), and poultry (Gaines et al., 2001a; Taylor et al., 2003), and glufosinate-tolerant corn grain and corn silage fed to dairy cows (Faust et al., 2007). Fewer data are available on herbicide tolerant transgenic corn for beef cattle. Erickson et al., (2003) reported results from 3 experiments where glyphosate-tolerant corn was compared with genetically similar or commercial, nontransgenic corn fed to finishing cattle. The authors reported that DMI, ADG, and G:F were similar between the glyphosate-tolerant corn and the 2 commercial hybrids in all 3 experiments. Likewise, the glyphosate-tolerant corn was not different ($P > 0.08$) than the genetically similar, nontransgenic corn in all 3 experiments. In all cases, carcass weight, marbling, and LM area were unaffected because of corn source fed in their experiment.

No other studies with beef cattle are available evaluating a combination of transgenic traits similar to the current experiment. A similar experiment was conducted using broiler chickens fed corn grain with this specific event (DAS-59122-7) by McNaughton et al. (2007). The authors concluded that no significant differences were detected for growth performance and carcass yields between 59122 and the near-isogenic control. Likewise, a similar performance study was conducted with laying hens using 59122 corn (Jacobs et al., 2008). The authors concluded that BW and gain, egg production, egg mass, and feed efficiency for hens fed 59122 corn were not significantly different from the respective values for hens fed diets formulated with near-isogenic corn grain.

Given the data available evaluating transgenic traits alone or the few studies in other species of combination transgenic traits, along with the performance and carcass characteristics from this experiment, we conclude that feeding transgenic corn containing the *cry*34Ab1 and *cry*35Ab1 genes from a Bt strain and the *pat* gene from *Streptomyces viridochromogenes* is nutritionally equivalent to commercial (nontransgenic) corn grains when fed to finishing cattle.

IMPLICATIONS

Performance and carcass characteristics of steers fed transgenic corn containing a combination of CRW protection and herbicide tolerance is nutritionally equivalent to nontransgenic corn. Feedlot cattle can be fed corn grain containing this transgenic event and no adverse effects are expected, yet crop producers will gain the agronomic advantages of corn rootworm protection and herbicide tolerance associated with these traits.

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